Section 1002
COST COMPONENTS

The selection of the proper cost components or factors and the use of reasonably accurate data are important parts of making a life-cycle cost analysis. The recommended cost factors for use in the analysis are design, construction, maintenance, rehabilitation, user, and salvage. It should be noted that costs that are common to each of the alternatives being considered should not be included in the analysis.

The alternatives more commonly considered for structural resurfacing, reconstruction or rehabilitation are:

- Remove and replace with new Portland Cement Concrete pavement (PCCP)
- Remove and replace with new Asphalt Concrete Pavement (ACP)
- Overlay with either ACP or PCCP.

The Regional materials Engineer and the Pavement Design Engineer coordinate all details regarding the design of alternatives

1002.01 Initial Costs

The two different types of costs that are included as initial costs are design, and construction. Design costs need to be included only if the cost of designing one alternative is different from those of another. If the design costs for all alternatives being considered are identical then it should be so noted and not included in the analysis. The source of information for design costs would be bid design hours.

One of the most important cost components is construction cost. This cost component is used by more agencies than any other component. The source of information for construction costs would be previous bids, previous projects and historical cost data. Use the most current and most accurate data available. When new materials or techniques are being considered as part of alternatives where previous bids or contracts are not available, then care should be taken in generating the estimated costs for those items. If there is a possible range in cost for new items, then it may be desirable to run a sensitivity analysis to determine the effect of cost variations on the end result.

Reflect all unique costs associated with each alternative for construction costs. For example, account for different roadway sections and material quantities for each alternative. Because of repetition, common items such as bridge and embankment widening, guard rail replacement, etc., should not be included in the analysis. Each overlay option requires some grade adjustment of adjacent ramps, guard rails, barriers, etc. Added costs, unique to each alternative should be included in the analysis.

1002.02 Maintenance Costs

These costs are those associated with maintaining the pavement surface, etc., at some acceptable level and are one of the most difficult areas to deal with in LCC analysis. Inherent problems exist in obtaining accurate and reliable maintenance costs. The type and extent of maintenance work performed at various time intervals into the future directly influences the cost of pavement maintenance. Predicting the type of maintenance required and the time frame very far in advance is the main problem. Maintenance needs are influenced by pavement performance. This area needs further work in order to improve prediction capability.

To help alleviate some of the prediction problem and to possibly provide the precision needed in LCC analysis the following is provided. National Cooperative Highway Research Program (NCHRP) Synthesis 46 provides some direction on how to improve the reliability of maintenance cost data.[1] NCHRP Synthesis 110[2] and 77[3] provide help to agencies in improving their capability for predicting future maintenance needs and costs. Studies have been accomplished comparing performance characteristics and maintenance costs. The differential in maintenance requirements for the various alternatives being considered is the most important item. If maintenance costs are identical for all alternatives, then there would be no need to include maintenance in the analysis.

Maintenance costs can also be adversely affected if a maintenance activity is delayed. For example, as pavement condition decreases, the cost of maintenance significantly increases. NCHRP Synthesis 58[4] provides extensive details on delayed activity. Also adversely affecting maintenance costs are truck load limits.[5] Pavement performance and costs significantly change with the failure to enforce weight limits.

Consider the same relational effect for all projects and maintenance costs.

1002.03 Rehabilitation Costs

These costs are those associated with pavement rehabilitation or restoration activities. Typical costs include chip seal coat, fabric interlayers, asphalt-rubber interlayers, open-graded friction course, and dense-graded asphalt concrete.

Compute costs consistent with and in the same manner as initial construction costs. With respect to pavement rehabilitation, projects are normally bid and constructed under the same criteria as new pavement construction. When considering rehabilitation costs relative to LCC analysis, two time frames come into play. The first time frame applicable to many projects begins at "time zero." This constitutes the beginning of an LCC analysis and applies where the pavement existed for years, requiring long-term improvements. In this case, treat rehabilitation similar to initial construction. The second time frame applies to future needs for a new pavement or a newly rehabilitated pavement. Accurate prediction of the future time when rehabilitation might be required is a major problem. When required, make the best estimate possible of the future time period using good historical performance data. Sensitivity analysis varying the time to rehabilitation helps determine to what extent time alters the final design selection.

The long time frames involved almost guarantee the occurrence of new materials and techniques applicable to the rehabilitation of pavements. Study these new materials as soon as possible using laboratory evaluations and project experimentation before the materials general use.

Consider only those projects demonstrating a high success rate for widespread use.

1002.04 User Costs

These costs are those associated with vehicle operating costs such as fuel consumption, parts, tires, etc. and user delay costs such as denial-of-use, delays due to speed changes, speed reductions, and idling time. Include these costs in the LCC analysis to the extent they might affect the choice of pavement alternatives.

Considering different surface types at the same general performance level, usually data are not precise enough to detect vehicle operating cost differences between two pavements. When considering paved versus unpaved roads and smooth versus rough pavements, significant user cost differences exist. For example, vehicle operating costs including fuel consumption increase as the pavement roughness increases. Deteriorating pavement caused cost increases result in higher rates for freight and bus transportation services. Higher costs directly affect minimum allowable pavement performance levels and maintenance policies.

High user delay costs result from slow downs caused by construction and maintenance activities and denial-of-use costs stemming from the closure of a section of highway during major repairs. Increased vehicle operating costs result when longer alternative routes and traffic stoppage and slow down caused by construction, rehabilitation, and maintenance occur.

The American Associations of State Highway and Transportation Officials (AASHTO) "A Manual on User Benefit Analysis of Highway and Bus Transit Improvements" or "Red Book" provides a reference for user costs in addition to the ones mentioned previously.

Assess the relative effect of user costs for different alternatives using sensitivity analysis if sufficient applicable data can be identified for the project being studied. Only three of forty-nine agencies taking part in Peterson's study, providing data for LCC analysis, utilize user costs. None identified any source data.

If used, one method for determining user costs follows a 1986 California Department of Transportation study. The study found the average value of time to be $6.25 per vehicle-hour of delay. Based on a four percent inflation rate, $11.25 would be used in 2001 calculations. Modify this for 2001 and future years based on the inflation rate chosen by the Value Engineering Section.

Use the following equation to determine user costs.

UC=(AVT)[(L/RS) - (L/IS)](ADT)(PT)(CP)

where	UC	=	User Cost
	AVT	=	Average Value of Time ($11.25 or as determined)

L	=	Project Length
RS	=	Reduced speed through construction zone
IS	=	Initial speed prior to construction zone
ADT	=	Average daily traffic in current year (only portion of ADT affected by the project
PT	=	Percent of the traffic affected by the construction project. Perform traffic study to determine percent of traffic using facility during the period.
CP	=	Construction period

Consider the inclusion of User Costs very carefully given their lack of use.

1002.05 Salvage Value

These costs are those remaining at the end of a life cycle analysis. Because this value can be either positive or negative, salvage value may be more appropriately call residual value. Due to the nature of pavements, some remaining life or value may by left for an alternative after completing the analysis period. Of the study group mentioned earlier, only 12 agencies indicated the consideration of salvage value as part of their LCC analysis in the selection of pavement alternatives. Base the determination of value on such factors as percent of pavement life remaining, experience, and historical data.

While a positive value for useful salvageable materials or remaining life may exist, a negative value exists if it costs more to remove and dispose of the material than it is worth. Include a salvage or residual value, positive or negative, in the LCC analysis if one can be assigned to a given pavement alternative at the end of the analysis period. Bring the value back to its present worth (PW) using the PW equation discussed previously. Use the proper discount rate and analysis period. If the alternative comparison is based on present worth use the PW cost for the appropriate alternative. Use average yearly cost or benefit if the comparison is annualized. The equation to convert present worth to annual costs follows the PW equation discussion.

One method of calculating salvage valve follows the following equation.

$$SV = (CC)[(ERL)/(TEL)]$$

where	SV	=	Salvage Value
	CC	=	Last construction or rehabilitation cost
	ERL	=	Expected remaining life
	TEL	=	Total expected life

1002.06 Energy Costs

Costs associated with energy are normally part of construction, maintenance, and rehabilitation costs. These costs are not included separately in LCC analysis. Analysis as a separate factor would be extremely difficult. Therefore, consider energy factors as one of the other factors after the LCC analysis is complete. In that energy costs are part of other costs they are not independent or overriding factors.

1. Transportation Research Board, *NCHRP Synthesis 46: Recording and Reporting Methods for Highway Maintenance Expenditures*, Transportation Research Board, National Research Council, Washington, D.C., 1977.

2. Transportation Research Board, *NCHRP Synthesis 110: Maintenance Management System*, Transportation Research Board, National Research Council, Washington, D.C., 1984.

3. Transportation Research Board, *NCHRP Synthesis 77: Evaluation of Pavement Maintenance Strategies*, Transportation Research Board, National Research Council, Washington, D.C., 1981.

4. Transportation Research Board, *NCHRP Synthesis 58: Consequences of Deferred Maintenance*, Transportation Research Board, National Research Council, Washington, D.C., 1979.

5. Carmichael, R.F., III, F.L. Roberts, P.R. Jordahl, H.J. Treybig, and F.N. Finn, "Effect of Changes in Legal Load Limits on Pavement Costs," Vol I, *Development of Evaluation Procedure*, Report No. FHWA-RD-79-73 and Vol II, *Users Manual for Program NULOAD*, Report No. FHWA-RD-79-74, Federal Highway Administration, Washington, D.C., 1978.